

# SCIENCE INSTRUMENT FAA CERTIFICATION PROCEDURES MANUAL

## Section 400: Electrical

### 400 Electrical Guidelines

The electronics subsystems within the scientific instruments (SIs) are largely low-power signal processing electronics. All SI electronics are nonessential equipment for aircraft operation, so the chief issues for certification are simple safety concerns. The certification process we describe here is geared toward identifying and communicating areas of potential concern with a series of block diagrams and worksheets. These will describe the SI electronics subsystem characteristics in sufficient detail to allow engineering personnel to evaluate the subsystems and their potential side effects.

#### 400.1 Principal concerns

Considering typical scientific instrumentation electronics and expectations for aircraft systems, the main concerns for the electronics subsystems are:

1. Radiated electromagnetic interference with aircraft systems
2. Materials choices, particularly with regard to flammability and toxicity (type of wire, for example).
3. Electrical shock hazards
4. Motions of remotely-controlled mechanisms
5. Proper securing of wire to prevent chafing
6. Control of energy sources.

#### Other aircraft systems

In this document we concentrate on safety issues peculiar to the electronics. Some issues are absorbed by certification of other systems on the aircraft:

1. All power to SIs will be buffered by the MCCS and controlled by flight crew personnel. Uninterrupted power supplies are not allowed. SI power can be remotely cut by certified equipment within the MCCS or by flight crew personnel in the event of pressure drop, interference, fire, or other real or suspected problems. (The corollary to this is that instrument builders should expect that the SI line power will be cut without warning in decompression or other emergency situations.)
2. The MCCS itself buffers the SI line power from the aircraft power, providing power overload and substantial conducted interference protection.
3. SI computer commands to the telescope pass through the MCCS and TA software. There they undergo reasonableness checks prior to execution. There are no SI software commands to any other aircraft systems; therefore software certification is not necessary for the SI.
4. Mechanical mounts and restraints for the electronics are part of the SI structural analysis and certification.

**General instrument design philosophy**

The instrument design and evaluation will follow a natural hierarchy to ensure flight safety:

1. Eliminate potential hazards by design. For example: materials choices, correct sizing for power supplies and interconnections, choosing connector types to eliminate potential overloads, and providing proper grounding, shielding, and bypassing.
2. Include safety devices. For example, correct electrical fusing, over-temperature shutdowns, torque limiting clutches or circuits for mechanisms such as circuit breakers.
3. Include warning devices. Some SIs may have operating modes that require annunciators, which indicate that parts of a SI are energized, or that a mechanism may move. The SIs are automatically well monitored because all parts of the SI will be in areas occupied by trained personnel who will be aware of unusual SI performance.
4. Provide special procedures and training. Portions of some instruments (e.g. gas lasers) may need to be operated by trained personnel.

**400.2 Documentation**

The first step is for the SI builder to clearly communicate the overall contents of the electronics system to the engineers who must understand and certify it as airworthy. These engineers need to understand the system at a level that allows them to identify and evaluate potential problems and specify tests or actions that will make the electronics systems certifiable.

**400.2.1 Block diagram**

It will be necessary to produce a block diagram of the overall electronics system. The purpose of this diagram is to identify all major subsystems and to show their interconnections in a way that the DER can get a sense of the entire system with an eye to identifying potential safety concerns.

**400.2.1.1 Subsystem and interconnections description worksheets**

The system block diagram should be accompanied by a standard form worksheet (to be provided) with brief notes on each subsystem's characteristics its interconnections, particularly:

- a. Subsystem purpose
- b. Typical power, voltage, and current levels for the input and output signals
- c. Connector types and wiring type and size for these signals
- d. Behavior when the inputs or outputs are internally or externally overloaded
- e. Approximate power consumption

- f. Power source (e.g., internal, external common DC supply, batteries)
- g. Location of power source and power control
- h. Clock or oscillator frequency ranges, waveforms, and power levels
- i. Magnetic field strength, time rate of change, shielding (e.g., ADR or SIS magnets)
- j. Any mechanical motions the subsystem controls
- k. Any liquids or gases the subsystem controls
- l. Any heating or cooling, including operating temperature range and limits
- m. Any commands the subsystem sends to the MCCS.  
Whether the subsystem is custom-build or a commercial item
- o. Packaging
- p. Approximate mass
- q. Materials
- r. Mounting (for reference; this is covered in structural)
- s. Location
- t. Any unusual features or items of safety concern

#### 400.2.2 Failure analysis worksheets

A second set of worksheets will be simple failure analyses.

400.2.2.1. What are the ways the electronics subsystem can fail that will affect safety?

400.2.2.2 If the system fails, what are the consequences and remediation paths?

Other than fire, few SI electronics systems are able to fail in a way that affects safety. The standard remediation path for fire will be using fire-resistant materials, having easily accessible remote power control for the entire instrument circuit, and having suitable fire extinguishers in easy reach of crew members designated and trained to extinguish small fires.

#### 400.3 Analysis

Based on this system breakdown, the DERs and other engineering staff will probably request supporting materials or suggest changes. Some of the supporting information might be:

Manufacturer's documentation showing compliance with UL or other standards

Laboratory measurements of conducted or radiated emissions from certain subsystems.

Power analysis for power supplies, fusing, wire size and material.

Procedures for assembly, servicing, or some other process.

#### **400.4 Testing**

Once they have reviewed the block diagrams and component descriptions, the DERs will identify the tests and procedures that will need to be made, and how these data will be taken and presented. The purpose of the instrument design and laboratory testing is to prepare the SI for testing in the aircraft. For example, the DERs may require inspection of fusing and wiring, or tests of some components in anechoic shield chambers to ensure that they meet industrial guidelines (RTCA/DO-160C Section 21). Industry experience indicates that most commercial equipment that meets FCC requirements for radiation and interference causes no problems on aircraft as long as they are not close to sensitive points; the intention is to keep SI stations far from sensitive areas.

SI electronics have similar systems. Sensitive IR arrays are sampled converted to digital and transmitted over an optical fiber to a host computer for processing and storage. There are controls for temperature, sensor sensitivity, and filter selection. Due to the similarity of electronics in the SIs and in the construction and mounting of the electronic boxes, it is anticipated that the first SI will require bench testing for Electro-Magnetic Interference (EMI) in accordance with industry standards. Follow-on instruments, when similarity allows, should only require EMI testing during the ground and flight test portion of their certification.

The real test of the shielding and isolation is whether any SI subsystems interfere with aircraft systems in flight. Ground tests in the aircraft after installation, characterization in the Science Interface Laboratory (SIL) before installation, and some laboratory tests may indicate potential problems, but the flight test is the only one that really counts.

#### **400.5 Design Issues**

##### **400.5.1 Conducted and Radiated Electromagnetic Interference**

Since the SI equipment is nonessential, the FAA's concern will be that conducted and radiated signals from the SI do not interfere with flight or personnel safety. Susceptibility of the SI to interference is an Observatory rather than FAA concern. Interference prevention on commercial flights is driven by the fact that passenger devices are untested and used in an uncontrolled way. SOFIA's preflight and flight-testing ensures that this is not the case for SI instruments, and we expect to

demonstrate compliance with critical parts of SI electronics powered up during takeoff and landing.

For conducted interference, standard good practice filtering on power supplies (e.g., line filters) will almost certainly provide adequate decoupling from the aircraft's systems, and the MCCS power converter's buffering provides yet another layer of isolation.

Radiation from computers, high-speed data links, motors, and microwave components in heterodyne systems does not seem to be an overwhelming problem if the instrument builder is reasonably careful about shielding, filtering, and decoupling. Well-grounded conductive instrument cases, commercial filtering feedthroughs, and semi-rigid cable for microwave coherent signals are likely to prevent most problems.

The facility cabling between the telescope and SI station will be properly shielded. Building equipment that does not break the shielding integrity of this system (e.g., using matching connectors into shielded boxes) will reduce radiation from the long interconnection cable runs. Use of the Observatory cable bundle will be a requirement.

The aircraft systems are most sensitive to interference in the communications and navigation bands. Weak radiation outside these bands is unlikely to be an interference problem. As a point of information, typical frequency bands for 747SP receivers and transmitters (Rx/Tx) are:

ADF	0.150 - 1.75 MHz	Rx
HF Comm	2.0 - 30.0 MHz	Tx/Rx
MB	75 MHz	Rx
VHF Nav	108.0 - 118.00 MHz	Rx
LOC	108.1 - 111.95 MHz	Rx
VHF Comm	118.0 - 135.95 MHz	Tx/Rx
UHF Satcom	1590-1610MHz	Tx/Rx
GS	225.0 - 400 MHz	Rx
ATC Xpndr	1090 MHz	Tx/Rx
Tacan/DME	1025 - 1150 MHz	Tx/Rx
GPS	1227.6 - 1575.42 MHz	Rx (SOFIA install)
Radio Alt	4200 - 4400 MHz	Tx/Rx
TCAS	1090 MHz	Tx/Rx
UHF Comm	850 MHz Tx 895 MHz Rx	Tx/Rx
Wx Radar	9375.0 +/- 40 MHz	Tx/Rx

The table above suggests that low harmonics and subharmonics of 100 MHz will fall outside most aircraft system bands. (As a parenthetical SI

susceptibility note, the HF transmitter can be in the hundreds of watts range; VHF communication and navigation transmitters in the tens of watts; and radars and altimeters in kW range but directional and shielded.)

#### **400.5.2 Lasers and other beamed electromagnetic radiation**

Radiation from lasers and other coherent sources, in addition to not interfering with flight safety, must meet existing safety standards for eye protection and power density limits. Most lasers typical to SI have low power, so eye protection procedure is the main concern. High-power, free-space beams with sufficient power to melt or burn must be completely enclosed in nonflammable structures that attenuate the power to safe levels over the generator's range of operating frequencies.

#### **400.5.3 Grounding**

No external part of the SI may have a hazardous voltage with respect to the aircraft ground potential under any conditions. Instrument cases which need to float with respect to ground should either contain circuits that limit currents and voltages to safe levels under all conditions (including power supply failures) or have appropriate ground fault sense and power interruption (GFI) circuits. Safety grounds and power returns are to be kept separate.

#### **400.5.4 Power supplies and fusing**

The SI may not overload the 60 Hz power supply provided by the MCCS. Documentation and possible tests of average and peak power loads, wire sizing, wire materials, and fusing will almost certainly satisfy the requirements.

#### **400.5.5 Batteries**

Batteries in SI will typically be low capacity devices, providing low-noise power for sensitive preamplifier circuits or backup power for clocks and computer memory.

Safe cell temperatures and pressures must be maintained during any probable charging or discharging condition. No uncontrolled increase in cell temperature may result when the battery is recharged (after previous complete discharge). This should be shown by tests if no previous data are available.

Explosive or toxic gases emitted may not accumulate in hazardous quantities within the airplane.

Corrosive fluids or gases that may escape from the battery may not damage surrounding airplane structures or adjacent essential equipment.

#### **400.5.6 High Voltage**

The FAA requires pressure or other interlocks to prevent arcing in the event of cabin decompression for devices with high voltage (CRTs, also PZTs, lasers, and their power supplies). This requirement will be taken into the MCCS

and need not be satisfied by individual SIs. Voltages and mechanical clearances must be sufficient to prevent arcing at altitudes above 8000 feet.

#### 400.5.7 Construction and electronic components

Wiring and circuit materials should be self-extinguishing either by material choice or by enclosure in metal boxes that are sufficiently airtight to extinguish any fire that might break out from component failure.

Outside of closed boxes, wire that meets the FAA criteria for flammability FAR Part 25 Appendix F (60-degree vertical flame test for wire). Mil-Spec connectors should be standard. Exceptions will be difficult to certify. Acceptable wire and known sources may be found in the chart below. There are several other acceptable sources.

Wire Application	Specification	Sources	Telephone
Outside of Boxes	Mil-W-22759	A. E. Petsche Weico Wire and Cable Electronic Cable Specialists	817-277-2887 516-254-2970 414-421-5300
Internal Box	Mil-W-22759 or Mil-W-16878	A. E. Petsche Weico Wire and Cable Electronic Cable Specialists	817-277-2887 516-254-2970 414-421-5300
Shielded Wire or Cable Assemblies	Mil-W-27500	Vermillion Inc. A. E. Petsche	316-942-8238 817-277-2887
Co-axial Cable	Mil-C-17	PIC Wire and Cable	414-246-0500

Since the SI electronics are nonessential equipment, the FAA has determined that commercial or industrial grade parts are acceptable at the components level as long as they meet the safety requirements.

#### 400.5.8 Use of Commercial Off The Shelf (COTS) Equipment

The FAA has certified aircraft that have UL-approved commercially packaged and assembled equipment. Some of the certification may benefit from instruments that are UL and FCC compliant.

Guidelines for this equipment are:

Must have a metal case that will contain an internal fire or is sufficiently airtight that internal ignition sources cannot cause a fire; or located and installed where a fire cannot damage safety-related parts, propagate to flammable parts, or cause personal injury.

Standard commercial wire may be used inside video or audio tape players or other passenger convenience or entertainment equipment purchased on the commercial market where similar, economically-feasible equipment having wire approved to Appendix F of FAR 25 does not exist. In such cases, the equipment should be located where smoke or fire would readily be noticed, and a readily identifiable switch, located away from the equipment, should be provided to enable its safe and rapid disconnection.